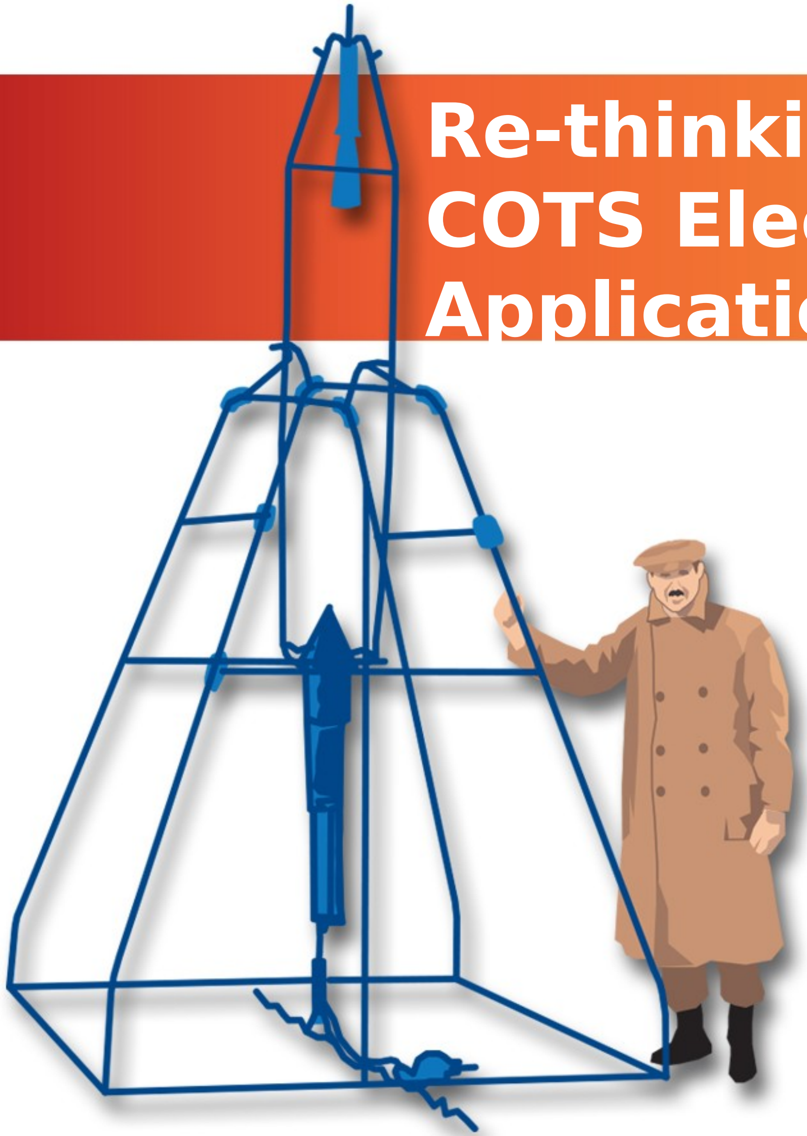
National Aeronautics and Space Administration

Re-thinking the Approach to COTS Electronics for Space Applications



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Outline

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- NASA-STD-8739.10 Overview
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- Three-option parts assurance
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The world has changed

- The MIL-SPEC system was devised when there was limited manufacturing capability for electronics – there was little assurance that parts would work reliably
- Parts were designed prescriptively and quality metrics were established relative to the designs
- Since there were no established reliability or statistical process controls, we had to use extensive strict quality requirements to make sure that current products had minimal variability relative to previous products
- MIL-SPEC levels that involved progressively more testing, higher sample sizes, and more stressing testing were introduced
- Since then commercial manufacturing capability with statistical process controls and high-volume production dwarfed and far surpassed the MIL-SPEC system.
  - With high-volume and statistical process controls, reliability now can be established directly
  - NASA and DoD did not recognize the advanced capability of the commercial sector and demanded additional screens to be applied to parts to try to make them mimic MIL-SPEC parts and hopefully screen in quality and reliability
    - Documentation stated (with limited justification in specific contexts) that higher levels equated to higher reliability, but actually quality was conflated with reliability in general
- As technology evolved, the MIL-SPEC parts could not keep up
  - Attempts to apply MIL-SPECs to noncompliant parts became more futile as part technologies have evolved

Current Conflicts

- MIL-SPECs, by definition, fundamentally limit technology
  - The broad environmental ranges required and the ability to tolerate many forms of overtest (inherently a derating), drive firm "catalog limits", which have been in place since inception
  - There are not and will not be well-defined "parts categories" to cover many new classes of electronics technology
- **"Special drawing" parts (e.g., from GSFC or DLA) extend the range, but current needs have already surpassed performance limits, they involve huge costs/lead times/MOQs, and are small batch builds**
- The use of MIL-SPECs to accept and qualify COTS parts conflicts with many of the premises of COTS parts
  - MIL-SPECs involve many test levels that are not based on the actual manufacturing processes or application use of the parts
  - COTS parts are optimized to levels laid out in their data sheets, which would very often be different from MIL-SPEC testing levels (neither necessary or sufficient for properly characterizing the parts for acceptance)
    - MIL-SPEC testing levels can overtest COTS parts, resulting in misleading data and/or reduced reliability and damage to parts

Soon there will be no choice

- Instruments are appearing for high end missions that cannot be manufactured with MIL-SPEC parts or parts that can be effectively screened into compliance using EEE-INST-002
  - It is a virtual certainty this will be the case for the next major flagship space telescope
- Fully COTS spacecraft are soon to be ubiquitous and over time, some will stand out as long-term reliable
  - As long as we continue to equate EEE-INST-002 screening and qualification with reliability, we will continue to misrepresent reliable systems based on COTS as "unreliable".
  - Such spacecraft will always be frowned upon for usage within NASA
- Availability of MIL-SPEC parts, especially level 1 and many types of space-grade, is becoming a growing challenge, in addition to the growing excessive costs.
- **New designs using traditional parts must wait one-year+ for flight parts and often six-months+ for ETU parts, which is intractable when design iterations are required**
  - **This is resulting in pauses, cuts, and cancellations of projects, and will do so in growing fashion**

We've reached the brick wall

- For years we have been able to maintain our compliance approach for assuring parts.
- When more performance or power dissipation was needed, or smaller footprint, lighter weight, or power consumption was needed, we developed standard drawings to combine compliance and performance
- However, even modern technology parts from the past 10 years are demanding capabilities that the drawings cannot keep up with
  - You might need a daughter board to hold all the compliant capacitors you need to support your FPGA
  - Outside of all the risks and impacts from the addition of that board, what will you do with all the extra ESR?
- These special build parts do not have the volume to assure reliability or to make productive use of process controls, only to support reliability prediction
- While manufacturers are advancing processing capability along with the resilience needed designed in to support industries with critical safety needs and extreme environments such as automotive, we focus on traditional approaches of "ruggedizing" older technologies
- We have been minimizing our exploitation of innovative design and manufacture that is booming, at expense of agency capabilities

The immediate problem

- The traditional space community is frozen in decades-old electronics development approaches that stifle innovation and rely on obsolete parts that are being forced not to be obsolete at high, and growing, costs and lead times
- Missions are being canceled, paused, and cut, in many cases due to overruns that are at least partially traced to electronics challenges
- Engineering staff is being cut based on reduced project work, highly driven by excessive costs
- The growingly long and uncertain lead times add years of overrun given necessary design cycles
- Even engineering and proto versions of traditional parts have lead times that not only conflict with the necessary engineering unit development processes but also contribute to the overrun directly

Our current electronics development processes are snowballing out of control, largely due to reliance on obtaining traditional parts and materials that are effectively obsolete – a change is needed or missions will be unimplementable

Can we slow down the use of COTS?

- The use of COTS is already here, no matter what requirements we impose
  - The only question is whether we want to put a spacecraft on-orbit or not
- COTS parts are not brought forward into our projects because someone wants to save a few dollars or a few weeks or eke a little bit of extra unnecessary performance.
- COTS parts are needed in order to fly mature technologies from the last 25 years
- COTS parts are needed to make systems more reliable
- COTS parts are needed because they are available
- COTS parts are needed because they do not involve excessive costs

The use vs non-use of COTS in our systems is a simple prohibition question. There is no way to stop them – you simply need to place the right boundaries to properly use them without damaging them or inflating costs unnecessarily. The tighter boundary you place on them, the more likely you will encourage poor choices and bad practices

Current electronics approach

- Perform top-level circuit designs based on performance objectives
- Select as many parts as possible from a discrete set of traditional building blocks
  - Actives
    - 5962R, 5962F, etc. microcircuits
    - JANSR, JANSF, etc. discretes
    - Limited common ”space-grade” COTS components
  - Passives
    - CDR, CWR, etc. capacitors
    - M55342 resistors
    - G311 capacitors
    - 303XXX-XXX resistors
  - Custom magnetics
- Choose proto or engineering version, when available, of actives and COTS passives (or high MOQ extras that have earlier deliveries) and construct ETU/EDU list
- Quote and order flight and engineering boards
- Wait
- Build assemblies
- Test
- Iterate design and order new parts (both ETU and flight)
- Wait ...

The waiting time even for ETU/EDU parts is largely untenable under any constraints

Next generation approach

- Perform top-level circuit designs based on performance objectives
- Choose the best parts for the job that are readily available with maximum performance margin (e.g., 10 weeks or less) (alternate)
  - Integrate parts engineering into the process – choose the best available part out of options (when options exist) rather than compliance. No extra part testing or special drawing parts, but make copious use of AEC-qualified and space-enhanced plastic parts. Assure highest order of precedence available is chosen
  - Integrate radiation engineering fully into the process – full radiation consideration: parts, analyses, design approaches, testing, PEAL/similarity data
  - Integrate reliability engineering into the process
- Procure available parts and boards and begin testing
  - Iterate as needed with radiation, parts, and reliability engineering in the loop

It is likely that for many designs the traditional path will not be viable even with only one iteration

We start at the top (NPR 8705.4)

<table>
<tr><td rowspan="3">Electronics, Electrical, and Electromechanical (EEE) Parts</td><td colspan="4">Objectives:
Select EEE parts at an appropriate level for functions tied directly to mission success commensurate with safety, performance and environmental requirements.

Accepted Standard:
NASA-STD-8739.10, Electrical, Electronic, and Electromechanical (EEE) Parts Assurance Standard or OSMA endorsed NEPP interim standards</td></tr>
<tr><td>Class A:
~~Level 1 parts, equivalent Source Control Drawings (SCD) or requirements per Center Parts Management Plan.~~
Assurance Level 1 parts, equivalent Source Control Drawings (SCD), requirements per Center Parts Management Plan, or documented proven developer practices that have demonstrated results, consistent with the lowest level of risk tolerance, to achieve necessary performance.</td><td>Class B::
~~Class A criteria or Level 2 parts, equivalent SCD or requirements per Center Parts Management Plan.~~

Assurance Level 2 parts, equivalent SCD , requirements per Center Parts Management Plan, or documented proven developer practices that have demonstrated results, consistent with a low level of risk tolerance, to achieve necessary performance.</td><td>Class C:
~~Class B criteria or Level 3 parts, equivalent SCD or requirements per Center Parts Management Plan.~~

Assurance Level 3 parts, equivalent SCD , requirements per Center Parts Management Plan, or documented proven developer practices that have demonstrated results, consistent with a moderate level of risk tolerance, to achieve necessary performance.</td><td>Class D:
~~Class C criteria or Level 4 parts, equivalent SCD or requirements per Center Parts Management Plan.~~

Assurance Level 4 parts.</td></tr>
<tr><td colspan="4">EEE Parts Notes: The intent is always to select the most appropriate assurance level parts to meet mission needs and requirements. There is nothing to disallow or discourage the use of parts aligned with higher classification levels with no additional testing when they are available. However, it is highly discouraged to require higher assurance level parts as standard or across the board. It is also discouraged to screen and/or qualify parts to achieve compliance above the current recommended assurance level.</td></tr>
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NASA-STD-8739.10 overview

- “Parent” agency parts standard
- Provides the end-to-end guidance for parts assurance in the agency at higher level than specific screening and qualification guidance
- Introduces a few new items since EEE-INST-002
  - Level 4: COTS with no additional screening
  - Automotive and vendor hi-rel as level 3 compliant
  - Various updated technical references
- Next version will introduce some updates
  - Level will be “assurance level”, no longer ambiguous interchangeable reference to grade, reliability level, quality level, which are all significantly different
  - Will point down to two paths for parts assurance
    - Traditional: 8739.11 (based on EEE-INST-002)
    - COTS: Three-option parts assurance

How are automotive and hi-rel COTS defined?

- Declared by the manufacturer to be intended for reliable usage
- Characterized by extensive in-production and/or post-production screening or electrical testing as evidenced by one or more of the following
  - Description in the datasheet as designed for reliable usage with description why
  - Manufacturer-provided documentation, such as
    - Production Part Approval Process (PPAP) document
    - Quality Manual
    - Website detailed technical information provided
  - Parts are qualified to the pertinent AEC Q-category specification (Q100, Q101, Q200)
  - Production is managed under IATF 16949 quality management system (QMS)

Dual Path update to 8739.10

Traditional: NASA-STD-8739.11 (MIL-SPEC/compliance driven)	Three-option parts assurance (COTS/constraint-driven)
Traditional, proven designs	New designs
Older generation technology	Newspace developers
Minimal size, weight, and power constraints	Current generation technology
Long lead times tolerable	High constraints on size, weight, and power
Emphasis on MIL-STD quality definitions	Emphasis on modern manufacturing, high volume, and statistical process controls
Use MIL-SPEC or screen in quality	Use established reliability or strategic part testing results
Design iterations likely not feasible	Design iterations inherent

Three option parts assurance

Assurance Level	PEAL option*	MIL-SPEC option	COTS option
1	VHCAI or VHCWP1	Class S, V, Y monolithic microcircuits Class K hybrid microcircuits JANS discrete semiconductors FRL T, S, R capacitors and resistors or M123 FRL C and D tantalum capacitors	ILPM & relationship with mfr & Established Part & High Volume & 100% mfr electrically tested & Statistical process control & zero-defects policy
2	HCAI or HCWP2	Class B or Q monolithic microcircuits Class H hybrid microcircuits JANTXV discrete semiconductors FRL P capacitors and resistors FRL B tantalum capacitors	ILPM or AEC qualified under IATF 16949 & 100k or more in production & Minimum 1 year in production & AQL of 0.4 or better**
3	MCAI or MCWP3	Class M, N, T, or /883 monolithic microcircuits Class G, D, or E hybrid microcircuits JANTX discrete semiconductors FRL B capacitors and resistors	Automotive or hi-rel part from reputable (proven flight history) mfr or high-volume part, mfr relationship, low field failure rate
4	N/A	N/A	no restrictions

EAL option is a placeholder, terms defined in PEAL reference document
ow field failure rates or low DPPM/DPPB are appropriate alternatives

COTS vs Radiation

- There is no connection between COTS and radiation
  - Unfortunately, there are lingering unwritten definitions in the community for COTS, such as “not radiation hardness assured” or “not characterized for space”
- Use of any circuit with active parts in a space environment requires characterization or demonstration in an environment relevant to the target environment whether the parts are commercial-off-the-shelf or not
- About 4-7% of parts in a typical space BOM are actives requiring consideration for radiation in their pertinent circuits in space

Low risk Radiation Approaches

1. Traditional: RHA, lot-specific radiation testing, or analysis
2. Newspace conservative: Strategic radiation testing of active parts, combined with circuit and system design mitigations
3. Full system radiation-tolerant design and rad-hard by design approaches, with RHA or testing for front-line defenders and NVRAM

Radiation approach depends on environment, specific active parts used, shielding in the system, and organizational preference and has no relationship to the allowance of COTS

Parts Evaluation & Acceptance Lab (PEAL)

- Reconstitution of a major institutional capability that assured reliable parts usage in the early days of NASA
- Driven by the reality of COTS dominance in the market, the necessity to exploit commercial capabilities, and gain the confidence needed to fly parts in low-risk tolerance missions.
- Part testing approaches always begin with an interaction with the manufacturer and consideration of manufacturing approach
- NASA employees (JPL-inclusive) and in-house contractors
  - Select and procure parts for characterization
    - Consider unfamiliar parts used and proposed on new and recent missions as top priority
    - Gather input from scientists, component designers, instrument developers
    - **Primary focus should be on part technologies, though specific "part number" assessments should also be performed to properly evolve from current approaches and to monitor trends in specific part design changes over time**
  - Determine screening and lot acceptance tests (LAT) to be employed for future project usage
    - or determination that manufacturer screening/LAT or statistical process controls as designed are sufficient
  - Establish tactical and strategic radiation assessments
  - Perform reliability testing and analyses
  - Determine required post-procurement actions (if any) for each part
  - Maintain parts selection list
    - Part-number-specific assessments over time can be used to characterize evolving trends for some individual part designs to understand risks of obsolescence and the motivations for changes in part design and manufacture
- This is a strategic, Agency-level activity that provides structure for parts selection and acceptance for future missions, not a part acceptance laboratory for missions in development

Summary

- The combination of supply chain issues and evolution along with the need to fly current technology drive the need for broad use of COTS
- The evolution of technology and manufacturing processes has created an insurmountable differential between design/manufacture of parts and most MIL-SPEC-based upscreening processes
- Successful history of usage combined with the findings of the NESC COTS Phase 2 study demonstrate a readiness to step forward with an expanded use of COTS
  - There are many considerations and COTS encompasses an infinite trade space, so thoughtful implementation with proper engineering judgment is necessary
  - No cookbook will apply, so thoughtful engineering is needed
- The continued use of unavailable parts for new designs will result in fewer and fewer missions getting into orbit
- A long-term broad COTS usage approach in NASA will require a capability such as PEAL since there will never be guidance to cover all situations